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(71) Applicant (for all designated States except US):
PHARMA MAR, S.A. (ES/ES); Calle de la Calera,
3, Polígono Industrial de Tres Cantos, E-28760 Madrid
(ES).

(71) Applicant and

(72) Inventor (for SD only): RUFFLES, Graham, Keith
[GB/GB]; 57-60 Lincoln's In Fields, London WC2A 3LS
(GB).

(72) Inventors; and

(75) Inventors/Applicants (for US only): FAIRCLOTH,
Glynn, Thomas [US/US]; PharmaMar USA, Inc., 320
Putnam Avenue, Cambridge, MA 02139-4616 (US).
NUYEN, Bastian [NL/NL]; The Nederland Cancer
Institute/Slotervaart Hospital, Dept. of Pharmacology,Louwesweg 6, NL-1066 EC Amsterdam (NL). WEIT-
MAN, Steve [US/US]; Institute for Drug Development,
Cancer Therapy and Research Center (CTRC), 14960
Omicron, San Antonio, TX 78245-3217 (US).(74) Agent: RUFFLES, Graham, Keith; Marks & Clerk,
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(54) Title: KAHALALIDE F

(57) Abstract: New formulations and new uses of kahalalide F are provided.

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Kahalalide F

The present invention relates to kahalalide F, a peptide isolated from a herbivorous marine species of mollusc, *Elysia rufescens*.

BACKGROUND OF THE INVENTION

Kahalilide F is the subject of European Patent 610,078. The patent reports activity against *in vitro* cell cultures of human lung carcinoma A-549 and human colon carcinoma HT-29.

More information concerning kahalalide F is to be found, for example, in:

The absolute stereochemistry of kahalalide F. Goetz, Gilles; Yoshida, Wesley Y.; Scheuer, Paul J. Dep. Chemistry, Univ. Hawaii, Honolulu, HI, USA. Tetrahedron (1999), 55(25), 7739-7746.

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Kahalalides: bioactive peptides from a marine mollusk *Elysia rufescens* and its algal diet *Bryopsis* sp. Hamann, Mark T.; Otto, Clifton S.; Scheuer, Paul J.; Dunbar, D. Chuck. Department of Chemistry, University of Hawaii of Manoa, Honolulu, HI, USA. J. Org. Chem. (1996), 61(19), 6594-6600.

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The marine environment: A resource for prototype antimalarial agents. El Sayed, Khalid A.; Dunbar, D. Charles; Goins, D. Keith; Cordova, Cindy R.; Perry, Tony L.; Wesson, Keena J.; Sanders, Sharon C.; Janus, Scott A.; Hamann, Mark

T. Center the Development Natural Products, University Mississippi, University, MS, USA. J. Nat. Toxins (1996), 5(2), 261-285.

The antitumoral compound Kahalalide F acts on cell lysosomes. Garcia-Rocha, Mar; Bonay, Pedro; Avila, Jesus. 28049-Madrid, Spain. Cancer Lett. (Shannon, Irel.) (1996), 99(1), 43-50.

Kahalalide F: a bioactive depsipeptide from the sacoglossan mollusk *Elysia rufescens* and the green alga *Bryopsis* sp. Hamann, Mark T.; Scheuer, Paul J. Dep. Chem., Univ. Hawaii, Honolulu, HI, USA. J. Am. Chem. Soc. (1993), 115(13), 5825-6.

SUMMARY OF THE INVENTION

We provide new formulations and new uses of kahalalide F.

PREFERRED EMBODIMENTS

A combination of a non-ionic surfactant and an organic acid is suited for use with a bulking agent to give a lyophilised form of kahalalide F suited for reconstitution. Reconstitution is preferably effected with a mix of emulsifying solubiliser, alkanol and water.

The lyophilised composition preferably comprises mainly the bulking agent, such as at least 90 % or at least 95 % bulking agent. Examples of bulking agents are well known and include sucrose and mannitol. Other bulking agents can be employed.

The non-ionic surfactant in the lyophilised composition is preferably a sorbitan ester, more preferably a polyethylene sorbitan ester, such as a polyoxyethylene sorbitan alkanoate, especially a polyoxyethylene sorbitan

mono-oleate, for example polysorbate 80. The non-ionic surfactant typically comprises a few % of the composition, such as 0 to 5 % of the composition, for instance 2 to 3 % of the composition.

The organic acid in the lyophilised composition is typically an aliphatic acid, preferably a hydroxycarboxylic acid and more preferably a hydroxypolycarboxylic acid, notably citric acid. The organic acid typically comprises a few % of the composition, such as 0 to 5 % of the composition, for instance 2 to 3 % of the composition.

The amount of kahalalide F in the lyophilised composition is typically less than 1 %, or often less than 0.1 %, of the mix. A suitable amount is in the range 50 to 200 µg, say about 100 µg, per 100 mg of composition.

The emulsifying solubiliser for the reconstituting agent suitably comprises an polyethylene glycol ester, notably an ester of a fatty acid, more preferably a PEG oleate such as PEG-35 oleate. The emulsifying solubiliser is suitably 0 to 10 % of the reconstituting agent, typically about 3 to 7 %, say about 5 %. The alkanol is usually ethanol, and is suitably 0 to 10 % of the reconstituting agent, typically about 3 to 7 %, say about 5 %. The remainder of the reconstituting agent is water, and gives a reconstituted solution suited for intravenous injection.

Further dilution of the reconstituted solution with 0.9 % saline may be appropriate for infusion of the kahalalide F.

In a particularly preferred embodiment, the lyophilised composition comprises 100 µg kahalalide F; 75 to 125 mg, especially 100 mg, bulking agent; 1 to 3 mg, especially about 2 mg of acid; and 1 to 3 mg, especially about 2 mg, of non-ionic surfactant.

The preferred reconstituting agent then comprises 2 to 7 %, say about 5 %, emulsifying solubiliser; 2 to 7 %, say about 5 %, alcohol; and remainder

water.

The invention additionally provides kits comprising separate containers containing the lyophilised composition and the reconstituting agent. Methods of reconstitution are also provided.

The present invention further provides a method of treating any mammal, notably a human, affected by cancer which comprises administering to the affected individual a therapeutically effective amount of a pharmaceutical composition thereof prepared by reconstitution of a lyophilised composition of this invention. The present invention can be employed particularly for treatment of patients with refractory cancers that do not respond favourably to other treatments. In particular, the compositions of this invention can be employed after other chemotherapy has been tried and not worked.

In one embodiment, the reconstituted solution is prepared for infusion and is administered in a 3-hour infusion on concentrations of up to around 20 or 25 $\mu\text{g/ml}$, typically up to 15 $\mu\text{g/ml}$. Suitable infusion equipment preferably includes a glass container, rather than one of polyethylene. Tubing is preferably of silicone.

A further aspect of this invention resides in new uses for kahalalide F. In particular, we envisage its use against prostate cancer and in particular androgen-independent prostate cancer, breast cancer, colon cancer, non-small cell lung cancer, ovarian cancer and for treating neuroblastoma. Kahalalide F is also active against dedifferentiated and mesenchymal chondrosarcomas and osteosarcomas. The new reconstituted formulations provided by this invention may be employed for the new uses, though other compositions are possible.

Examples of pharmaceutical compositions include any solid (tablets, pills, capsules, granules, etc.) or liquid (solutions, suspensions or emulsions) with suitable composition or oral, topical or parenteral administration, and they may contain the pure compound or in combination with any carrier or other

phannacologically active compounds. These compositions may need to be sterile when administered parenterally.

Administration of the compounds or compositions of the present invention may be by any suitable method, such as intravenous infusion, oral preparations, intraperitoneal and intravenous administration. We prefer that infusion times of up to 24 hours are used, more preferably 2-12 hours, with 2-6 hours most preferred. Short infusion times which allow treatment to be carried out without an overnight stay in hospital are especially desirable. However, infusion may be 12 to 24 hours or even longer if required. Infusion may be carried out at suitable intervals of say 2 to 4 weeks. In an alternative dosing protocol, the kahalalide F is administered for say about 1 hour for 5 consecutive days every 3 weeks. Other protocols can be devised as variations.

Pharmaceutical compositions containing compounds of the invention may be delivered by liposome or nanosphere encapsulation, in sustained release formulations or by other standard delivery means.

The correct dosage of the compounds will vary according to the particular formulation, the mode of application, and the particular *situs*, host and tumour being treated. Other factors like age, body weight, sex, diet, time of administration, rate of excretion, condition of the host, drug combinations, reaction sensitivities and severity of the disease shall be taken into account. Administration can be carried out continuously or periodically within the maximum tolerated dose.

The compounds and compositions of this invention may be used with other drugs to provide a combination therapy. The other drugs may form part of the same composition, or be provided as a separate composition for administration at the same time or a different time. The identity of the other drug is not particularly limited, and suitable candidates include:

a) drugs with antimitotic effects, especially those which target cytoskeletal elements, including microtubule modulators such as taxane drugs (such as

taxol, paclitaxel, taxotere, docetaxel), podophylotoxins or yinca alkaloids (vincristine, vinblastine);

- b) antimetabolite drugs such as 5-fluorouracil, cytarabine, gemcitabine, purine analogues such as pentostatin, methotrexate);
- c) alkylating agents such as nitrogen mustards (such as cyclophosphamide or ifosphamide);
- d) drugs which target DNA such as the antracycline drugs adriamycin, doxorubicin, pharmorubicin or epirubicin;
- e) drugs which target topoisomerases such as etoposide;
- f) hormones and hormone agonists or antagonists such as estrogens, antiestrogens (tamoxifen and related compounds) and androgens, flutamide, leuporelin, goserelin, cyprotrone or octreotide;
- g) drugs which target signal transduction in tumour cells including antibody derivatives such as herceptin;
- h) alkylating drugs such as platinum drugs (cis-platin, carbonplatin, oxaliplatin, paraplatin) or nitrosoureas;
- i) drugs potentially affecting metastasis of tumours such as matrix metalloproteinase inhibitors;
- j) gene therapy and antisense agents;
- k) antibody therapeutics;
- l) other bioactive compounds of marine origin, notably the didemnins such as aplidine or ecteinascidins such as Et 743.

EXAMPLES OF THE INVENTION

Experimental work which underlies the present invention is described in the following Examples.

Example 1

Development of a lyophilized, parenteral pharmaceutical formulation of kahalalide F, KF

We have also found this drug to be neurotoxic at high concentrations in our assay system and which correlates well with animal data showing neurotoxicity above the maximum tolerated dose (MTD). Using a fluorescent viability stain (ethidium homodimer and calcein AM, Molecular Probes) coupled with immunocytochemistry, we determined that $\sim 10 \mu\text{M}$ Kahalalide is toxic to central nervous system (CNS) neurons (neurofilament positive) but spares astrocytes (glial fibrillary acidic protein positive) as well as sensory (substance P expressing) and motor (choline acetyl transferase positive) neurons in the spinal cord.

We conclude that Kahalalide F is a promising drug for the treatment of prostate cancer as its neurotoxicity is relatively mild at or below MTD levels. Further, preliminary data indicate that Kahalalide F may prove to be an ideal drug for treating neuroblastoma, if deliverable, due to its CNS neuron selectivity.

Example 4

Selective antitumor activity of kahalalide F

Kahalalide F is a lysosomal poison with *in vitro* selectivity for hormone-independent prostate tumors, neu⁺ (Her2 overexpressing) breast tumor cells and neuroblastomas. An extended MoA includes inhibition of erbB2 and blocking of the EGF receptor as well as inhibition of TGF α gene expression. Preclinical *in vivo* models have confirmed selectivity and sensitivity of hormone independent prostate tumors (PC-3 and DU-145) with a rodent MTD of 300 $\mu\text{g/kg}$ BW. *In vitro* antiproliferative studies show equivalent IC_{50} activities among certain prostate tumors (0.27 μM PC-3; 0.25 μM DU-145; 0.73 μM T-10, 0.24 μM DHM and 0.19 μM RB), but no activity to hormone-sensitive LnCAP. Other studies show selective, but slightly less potent IC_{50} activities to neu⁺ breast tumor cells (2.5 μM SK-BR-3; 2 μM BT-474) and to a neuroblastoma cell line (1 μM BE(2)C). *In vitro* exposure studies demonstrate that KF is not schedule-dependent. A minimum exposure of 1 hour is as potent as 48 hours, in most cases. Moreover, the immediate and delayed effects of cytotoxicity have the same pharmacodynamics and do not increase with treatment duration.

Phase 1 trials incorporating a daily times five, weekly schedule will begin soon in the evaluation of KF as a potential chemotherapeutic agent against solid tumors.

Example 5

Investigation of the Effects of Kahalalide F (PM92102) Against Human Tumor Specimens Taken Directly from Patients.

In vitro studies have shown activity of KF to cause cell swelling and ultimately death (Garcia-Rocha, et al., *Can Letters* 99:43-50). In the present study, fresh human tumor specimens were treated with KF to determine activity, utilizing the Human Tumor Cloning Assay. One hundred and four patient tumor specimens were treated with KF under 14-day continuous exposure at 0.01, 0.1, and 1.0 μM . Specimens were incubated in a 2-layer soft-agar cloning system at 37°C and were removed on Day 14 for colony count. Colonies formed in the treated plates were compared to the number of colonies formed in the untreated control plates, and the percent colonies surviving at each concentration was calculated. The positive control plates contained the cell poison orthosodium vanadate (200 $\mu\text{g}/\text{ml}$). Among these specimens, approximately 30% were evaluable with appropriate negative and positive controls. *In vitro* responses (inhibitory response indicated by 50% survival) were observed in 16% (5/31), 19% (6/31), and 81% (25/31) of the specimens at 0.01, 0.1, and 1.0 $\mu\text{g}/\text{M}$, respectively. There was a positive relationship between concentration and response to KF, with a significant response (81%) at the higher concentration tested ($1.0 > 0.1 > 0.01$). Notable responses were seen in breast (100%), colon (75%), non-small cell lung (100%), and ovarian cancer specimens (91%). KF is a promising anticancer agent, to which a broad spectrum of tumors responded.

Example 6

Phase I and pharmacokinetic study of Kahalalide F in patients with advanced androgen refractory prostate cancer

KF displays both in vitro and in vivo anti-tumor activity in various solid tumor models including breast, colon, non-small cell lung, and in particular prostate cancer. On the basis of its selectivity, KF is now further developed as a potential anticancer agent against androgen independent prostate tumors.

OBJECTIVE: In the present phase I clinical and pharmacokinetic (PK) study the toxicity profiles PK and anti-tumor activity of KF are investigated.

METHODS: KF is administered as an intravenous infusion over one hour, during five consecutive days every three weeks in patients with advanced or metastatic androgen refractory prostate cancer. On the basis of the MTD values defined in mice, a starting dose of 20 $\mu\text{g}/\text{m}^2/\text{day}$ was selected, which is equivalent to a total dose of 100 $\mu\text{g}/\text{m}^2$. PK of KF were determined in plasma during the first course. Bioanalysis of KF was performed by LC-MS/MS. LDH, AF and especially PSA levels of each patient were also evaluated during the study to determine the activity of KF.

RESULTS AND DISCUSSION: At present 7 patients have been registered. Patients had a median age of 66 years (range 54-75). One patient per level was entered at 20, 40, 80 and 160 $\mu\text{g}/\text{m}^2/\text{day}$. Due to transaminase elevation a number of 4 patients were entered at the current dose level, 320 $\mu\text{g}/\text{m}^2/\text{day}$. The first patient of this study was re-entered at this dose level. Observed adverse events were rapidly reversible mild headache, fatigue, pain and local edema. The only drug related toxicity to date was a rapidly reversible CTC grade 3 ASAT that occurred at 320 $\mu\text{g}/\text{m}^2/\text{day}$. PK revealed a linear relationship between dose and AUC over the whole dose range. Total plasma clearance was 267 mL/min (± 115) and the terminal half-life of intravenous KF in these patients was 0.46 h (± 0.13). Maximum plasma concentrations reached at the current dose level (35-50 ng/mL) are potentially active for prostate cancer in the clonogenic tumor assay (activity from 15 ng/mL). Thus far, the schedule is well tolerated. One patient showed a significant decrease in PSA level ($>50\%$) associated to clinical improvement (pain relief). Two additional patients experienced minor PSA reductions, one still ongoing after two cycles. The maximum tolerated dose has not been reached yet and the study is ongoing.

Example 7

Kahalilide F is cytotoxic to dedifferentiated and mesenchymal chondrosarcomas, CHSAs, and osteosarcomas, OSAs, as well as to hepatocellular and prostate carcinoma cells. It did not significantly inhibit the growth of CHSA and OSA cells, and was able to elicit a cytotoxic effect even if exposed to cells for as short as 10 minutes.

CLAIMS

1. A formulation of kahalalide F comprising a lyophilised mix of kahalide F, a non-ionic surfactant, an organic acid and a bulking agent.
2. A kit comprising a formulation of claim 1, together with instructions for dilution with a reconstitution solution of a mix of emulsifying solubiliser, alkanol and water.
3. The kit of claim 2, together with a supply of the reconstitution solution.
4. A reconstituted solution prepared from a formulation of claim 1 or a kit of claim 2 or 3.
5. A reconstituted solution according to claim 4, when reconstituted using a reconstitution solution of a mix of emulsifying solubiliser, alkanol and water.
6. A diluted reconstituted solution comprising a reconstituted solution according to claim 4 or 5 when diluted with 0.9 % saline to a concentration suited for infusion of the kahalalide F.
7. The use of a diluted reconstituted solution according to claim 6, in the treatment of cancer.
8. The use of kahalalide F against prostate cancer, breast cancer, colon cancer, non-small cell lung cancer, ovarian cancer, for treating neuroblastoma, or against dedifferentiated or mesenchymal chondrosarcomas or osteosarcomas.
9. The use according to claim 7 or 8, wherein the kahalalide F is administered by infusion about 1 hour for 5 consecutive days every 3

weeks.

10. The use according to claim 7, 8 or 9, wherein the kahalide F is administered in combination with another drug.
11. The use according to any of claims 7 to 10, wherein the kahalide F is administered to a refractory patient.